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Dundalk Sewershed Evaluation Study Plan
Project No. 1047
RJN Job No. 17-2252

Baseline Analysis and Capacity Assessment Report

Sanitary Sewer Overflow Consent Decree
Civil Action No. JFM-02-1524

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1.0 INTRODUCTION

1.1 Sewershed Description

The Dundalk sewershed, shown in **Figure 1-1**, is generally bounded by Eastern Avenue to the north, Inner Harbor to the south, Baltimore City/Baltimore County line (Central Avenue) to the east, and Newkirk Avenue to the west. Interstate 95 runs along the northwest border of the sewershed.

The Dundalk sewershed is about 2500 acres in size with approximately 153,000 lf of pipe ranging in diameter from 8-inch to 66-inch, 600 manholes and one pump station. The covered area is generally a combination of residential and commercial property with a heavy industrial component. Wastewater from all basins in the Dundalk Sewershed is collected at the Dundalk Pump Station and then discharged through a 36-inch force main to a 54-inch gravity interceptor. The wastewater is finally discharged to the Outfall Sewershed at one location before being treated at the City's Back River Wastewater Treatment Facility.

1.2 Objectives

This report describes capacity analysis of the hydraulic model established for the Dundalk sewershed under dry weather and a series of design storm events under baseline and future (Year 2025) conditions. The hydraulic model was calibrated in previous efforts in accordance with the BaSES manual. The purpose of this report is to evaluate transmission capacity in order to identify portions of the collection system with insufficient capacity and potential overflows.

2.0 BASES MANUAL REQUIREMENTS

2.1 Baseline and Future Conditions

Based on the Consent Decree, the conditions present in the sewer system at the time when the flow and rainfall monitoring were conducted in the Dundalk sewershed define the baseline conditions. Under the City's Project 995, flow meter and rain gauge data was collected for approximately a one year period from May 2006 to May 2007. The base year is therefore 2007 and future conditions are based on Year 2025 with projections for population growth and collection system deterioration. Notably, there are no Paragraph 8 projects in the Dundalk sewershed.

As required by the BaSES manual, RJN performed a capacity assessment under baseline and future conditions for two scenarios regarding operation of the Dundalk Pump Station:

(a) All pumps are online (3 main pumps and 1 backup pump)

(b) Backup pump is online (3 main pumps online only)

Note: The Dundalk Pump Station was designed to have 3 pumps operating with 1 backup pump available.

2.2 Design Storms

Seven design storms will be used to assess system capacity, and they are:

(a) 1, 2, 5, 10, 15, and 20 year, 24 hour duration storm events

(b) 3-month storm with duration equal to the time of concentration for the Dundalk sewershed

The time of concentration for the Dundalk Sewershed has been determined to be 1.5 hours and all design storm events were developed by the Technical Program Manager and provided to RJN. The return period, total rainfall depth, and peak intensity of each design storm are provided in **Table 1**, and rainfall distributions are provided in **Appendix A**.

Table 1
Dundalk Baseline Analysis and Capacity Assessment Report: BaSES Requirements
Design Storm Summary

Return Period (years)	Duration (hours)	Rain Depth (inches)	Peak 15-min. Intensity (in/hr)
3*	1.5	0.81	1.36
1	24	2.67	2.17
2	24	3.23	2.59
5	24	4.15	3.17
10	24	4.97	3.61
15	24	5.41	3.82
20	24	5.82	4.00

* This design storm has a return period of 3 months

3.0 FLOW COMPONENT DEVELOPMENT

The Consent Decree for the City of Baltimore establishes the requirements to properly estimate dry weather flow under baseline and future conditions. This section describes the derivation of dry weather flow components with particular focus on projections of future flows.

3.1 Residential flow and Population Projection

Population data in 5-year increments from 2000 to 2025 was obtained from the City and the data is based on an intersection of the GIS shapefiles for the Transportation Analysis Zones (TAZs) with the GIS shapefiles for meter basins or sewershed service areas (SSAs). TAZs are subdivisions of geographical areas that are delineated for land use and travel analysis purposes. In Baltimore, TAZs generally follow the census tract boundaries and provide pertinent geographical information such as population and number of households. Overall, the analysis indicates a 9.6% increase in residential wastewater flow over the 20 year planning horizon from 2005 to 2025. The population of 9,647 for 2005 is applied to base year 2007 in this study and the difference is expected to be insignificant.

The per capita wastewater generation rates are assumed to be constant over the 20 year planning horizon and they were calculated by dividing residential base sanitary flow by population (major industrial and commercial flows were excluded from 2007 wastewater flow).

3.2 Industrial and Commercial Flows

As discussed in **Section 1.1**, the Dundalk sewershed receives industrial and commercial flows and they are dominant in basins DU01, DU02, DU04, and DU05. A shape file for Top 100 Water Users in Dundalk for base year 2007 was obtained from the City. A return factor of 0.75 was applied to the water consumption data to account for flows that were not returned to the collection system. The Baltimore Metropolitan Council conducted a flow projection study up to Year 2025 and the City provided RJN with expected wastewater flow rates for each SSA in Dundalk. Future industrial and commercial flows were derived for each sub-catchment (if industry or commercial property falls within a sub-catchment) based on this flow projection study.

Throughout the development of the hydraulic model for the Dundalk sewershed, RJN requested new developer's agreements and researched changes in the sewer network and related wastewater flows. In particular, the General Motors manufacturing plant at 2122 Broening Highway and 5003 Holabird Avenue in basin DU01 was closed. Chesapeake Commerce Center and other properties are being or will be constructed at this site and new sewers will be in service prior to 2025. The sewer network at this site was updated correspondingly in the model for future conditions analysis (as well as in the City's GIS based on current record drawings). As the developer's agreements do not include design flows, the average wastewater flow from the new developments was estimated based on expected number of employees provided on the sanitary sewer construction documents and application of typical wastewater generation rates, e.g., 13 gallons per employee per day for office buildings (Metcalf & Eddy, Inc., *Wastewater Engineering*).

In addition, community housing south of O'Donnell Street and north of Boston Street in basin DU07 was demolished in 2008. Since no development was planned for the demolished area during the time of the study, Year 2025 residential wastewater flow for this area was assumed to increase by 9.6% over Year 2005 residential wastewater flow.

3.3 Base Groundwater Infiltration

According to a City memorandum issued on June 20, 2008 (RFI-34: Base Sanitary Flow Formula, BaSES 7.4.5), the Stevens-Schutzbach method was adopted to calculate base infiltration.

$$BaseInfiltration = \frac{0.4 \times MDF}{\left(1 - \left(0.6 \times \left(MDF \big/ ADF\right)^{(MDF)^{0.7}}\right)\right)}$$

Where MDF denotes minimum dry flow (usually occurring between 2 and 4 am in the morning), and ADF denotes the average dry flow.

Groundwater infiltration for base year 2007 was calculated from meter data and the groundwater infiltration of each sub-catchment within a meter basin was distributed proportionally based on contributing area. In accordance with the BaSES manual (Section 7.6.3), groundwater infiltration was increased by 10% to account for pipe deterioration in 2025.

3.4 Rainfall Dependent Inflow and Infiltration (RDII)

Since the Dundalk sewershed is highly developed, wet weather parameters determined through previous calibration efforts are assumed to be valid up to Year 2025. Notably, it was found during wet weather calibration of the model that all meter basins exhibited higher inflow and infiltration in response to winter storms than in response to summer storms. This behavior is because the ground is wetter and the groundwater table is higher in winter than in summer, leading to more inflow/infiltration per same amount of rainfall in winter than in summer. Nevertheless, it is understood that the design storms, behaving like summer storms, are of shorter duration and higher intensity. For the purpose of the system capacity analysis, a median R-value was tuned during calibration to ensure no significant bias toward any season. A map (**Figure 3-1**) is provided below to represent inflow and infiltration severity in the Dundalk sewershed.

4.0 CAPACITY ANALYSIS – DRY WEATHER RESULTS

This section of the report describes how the Dundalk sewershed hydraulic model responds to dry weather flows (i.e., base sanitary flow and base groundwater infiltration) under base year and Year 2025 conditions. Response to rainfall dependent inflow and infiltration in addition to such flows will be described in **Section 5**.

4.1 Baseline Conditions

The simulation first modeled dry weather flows on January 01, 2007 while all pumps at the Dundalk pump station are online. Simulation results suggested that all gravity sewers have sufficient capacity to handle peak dry weather flows and no surcharge or sewer overflow was predicted. **Appendix B** provides each pipe in the model, the peak flow, the pipe full capacity, and the percentage of capacity used under baseline and future conditions. Two maps (**Figures 4-2 and 4-3**) presenting the percentage of capacity used for each pipe under peak flow conditions are provided at the end of this section.

Table 2 summarizes pump station flows and levels, and peak velocity within the force main during dry weather under baseline and future conditions. The Dundalk Pump Station has 4 variable frequency drive (VFD) pumps and it has a design capacity of 33 MGD when three pumps are in operation at a nominal speed of 710 rpm, rendering the 4th pump as a backup pump. The variable frequency drive allows any of the 4 pumps to operate at speeds up to 895 rpm. The actual rotation speed of the motor and corresponding pumping rate of each pump depend on the magnitude of the incoming flow.

The Dundalk sewershed contributes an average inflow of 5.41 MGD and a peak inflow of 6.11 MGD to the pump station. One pump alone sufficiently handles dry weather flow with a peak pumping rate of 6.32 MGD (a motor rotation speed of 579 rpm). The pump lifts sewerage 85 feet (static head) from the wet well to the discharge end of the 36-inch force main (manhole S67S__019MH); the hydraulic profile for the full force main is shown in **Figure 4-1**. Nodes between the pump station and manhole S67S__019MH represent changes in gradient on pressure pipes and they are defined as “break” nodes in InfoWorks CS with no storage capacity. It is understood that velocities within the force main should not be excessive to cause scouring effect. As a rule of thumb, a velocity criterion of 7 feet per second is provided in Section 7.6.2 of the BaSES manual (Page 7-23). As shown in Table 2, the peak velocities in all cases remain below 7 feet per second during dry weather. As expected, simulation results while three pumps are online are the same.

4.2 Future Conditions

The next simulation modeled dry weather flows on January 01, 2025 while all pumps are online. Review of the data in **Table 2** indicates a 9.1% increase of dry weather inflow into the pump station from 2007 to 2025 due to population changes, industrial flow changes and sewer deterioration. Despite this, one pump handles Year 2025 peak dry weather inflow of 6.67 MGD. As with baseline conditions during dry weather, the simulation results are the same when one pump is offline for maintenance.

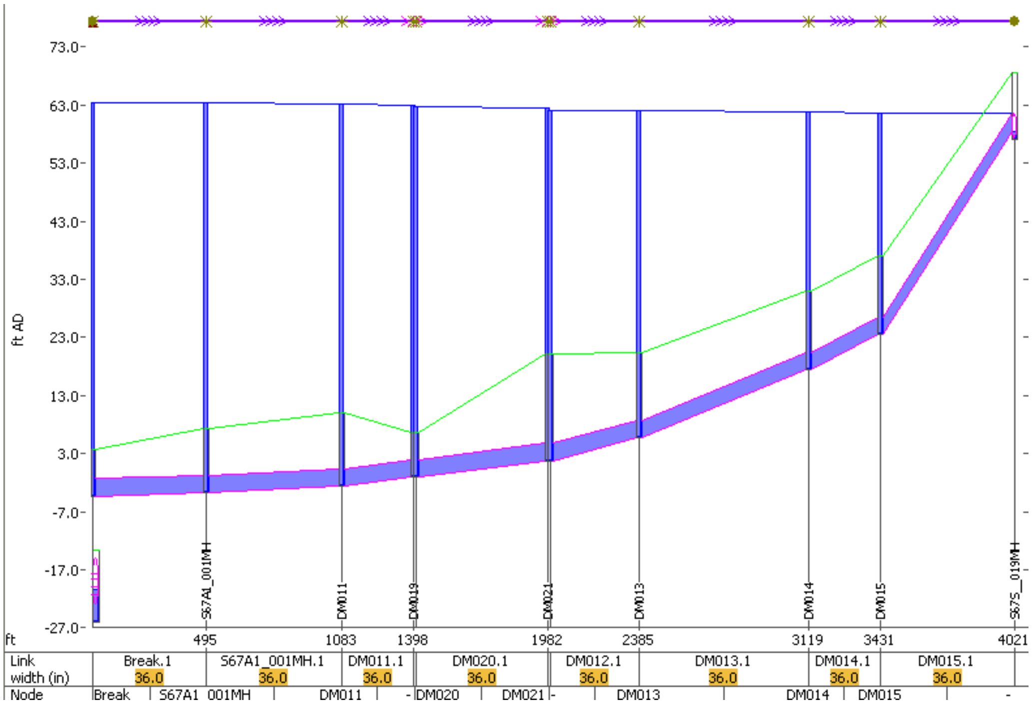


Figure 4-1: Hydraulic Profile for the force main

Table 2
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis – Dry Weather Results
Pump Station Summary

	Minimum Inflow (MGD)	Average Inflow (MGD)	Peak Water Level in Wet well* (ft)	No. of Pumps Operated	Peak Velocity in 36” Force Main (fps)	Peak Pumping Rate (MGD)
Baseline (All pumps online)	3.81	5.41	-20.7	1	1.38	6.32
Baseline (Backup pump offline)	3.81	5.41	-20.7	1	1.38	6.32
Future (All pumps online)	4.18	5.90	-20.7	1	1.52	6.94
Future (Backup pump offline)	4.18	5.90	-20.7	1	1.52	6.94

* The wet well has a depth of 12.5 feet. The rim elevation of the wet well was set to -13.5 feet to match field-collected rim elevation and invert data of manholes and pipes close to the pump station.

5.0 CAPACITY ANALYSIS – WET WEATHER RESULTS

A series of simulations were performed to analyze response of the Dundalk sewershed hydraulic model to seven design storms as specified in **Section 2.2** for baseline and future conditions under two scenarios:

(1) All pumps are online (3 main pumps and 1 backup pump), and
(2) Backup pump is offline (3 main pumps online only)

System performance was assessed with respect to pipe capacity, pump station capacity, force main capacity, and predicted sewer overflow. Results regarding occurrence of sewer overflow locations and flood volume are summarized in **Tables 3 – 6** for each storm event and pump station scenario.

Table 7 provides pump station and force main analysis results for peak wet weather conditions. Maps (**Figures 5-11 to 5-14**) presenting the results of the return period analysis are provided at the end of this section. The information on these maps indicates the storm frequency that creates flooding condition for a manhole and flow restriction for a pipe. The hydraulic flow restriction is performed by comparing the slope of each pipe to the slope of the hydraulic grade line at peak flow. A surcharged sewer with a pipe slope flatter than the slope of the hydraulic grade line indicates that the sewer has limited capacity to handle the peak flow (i.e., flow restriction). If the pipe slope is steeper than the slope of the hydraulic grade line, then the sewer is in a backwater condition caused by a downstream control. **Appendix C** provides the peak flow, the pipe full capacity, and the maximum surcharge state for each pipe in the model.

Table 3
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis – Wet Weather Results
Baseline Conditions Overflows – All Pumps Online

Basin	3-month Storm		1-year Storm		2-year Storm		5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)
DU01											S61Y_003MH	0.0074	S61Y_003MH S61W_007MH	0.0213 0.0058
DU02														
DU03							S63I_017MH	0.0006	S63I_017MH S65I_001MH S65G_011MH	0.0064 0.0028 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0094 0.0054 0.0002 0.0005 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0119 0.0074 0.0006 0.0010 0.0004
DU04														
DU05													S69A1_017MH	0.0008
DU06					S69W_008MH S69W_004MH	0.0009 0.0001	S71S_005MH S71S_004MH S69W_008MH S69W_004MH S69W_009MH S69U_004MH S71S_014MH	0.0673 0.0281 0.0116 0.0049 0.0015 0.0007 0.0011	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1073 0.1102 0.0244 0.0204 0.0038 0.0071 0.0050 0.0036 0.0017 0.0009	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1532 0.1293 0.0433 0.0253 0.0098 0.0081 0.0063 0.0055 0.0043 0.0023	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_011MH S69W_009MH S69U_004MH S69S_012MH	0.1894 0.1453 0.0633 0.0297 0.0158 0.0088 0.0070 0.0073 0.0074 0.0038
DU07					S69M_006MH	0.0012	S69M_006MH	0.0087	S69M_006MH	0.0188	S69M_006MH S71O_012MH S67M_012MH	0.0248 0.0013 0.0001	S69M_006MH S69O_006MH S71O_012MH S67M_012MH	0.0299 0.0021 0.0048 0.0030
Totals		0.000		0.000		0.0022		0.1245		0.3125		0.4366		0.5668

Table 4
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis – Wet Weather Results
Baseline Conditions Overflows – Backup Pump Offline

Basin	3-month Storm		1-year Storm		2-year Storm		5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)
DU01											S61Y_003MH	0.0074	S61Y_003MH S61W_007MH	0.0213 0.0059
DU02														
DU03							S63I_017MH	0.0006	S63I_017MH S65I_001MH S65G_011MH	0.0064 0.0028 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0094 0.0054 0.0002 0.0005 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0119 0.0074 0.0006 0.0010 0.0004
DU04														
DU05													S69A1_017MH	0.0010
DU06					S69W_008MH S69W_004MH	0.0009 0.0001	S71S_005MH S71S_004MH S69W_008MH S69W_004MH S69W_009MH S69U_004MH S71S_014MH	0.0679 0.0282 0.0116 0.0049 0.0015 0.0007 0.0011	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1096 0.1118 0.0244 0.0204 0.0038 0.0071 0.0051 0.0036 0.0017 0.0009	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1576 0.1313 0.0434 0.0253 0.0098 0.0081 0.0066 0.0055 0.0043 0.0023	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_011MH S69W_009MH S69U_004MH S69S_012MH	0.1948 0.1469 0.0634 0.0297 0.0158 0.0088 0.0071 0.0076 0.0074 0.0038
DU07					S69M_006MH	0.0012	S69M_006MH	0.0087	S69M_006MH	0.0188	S69M_006MH S71O_012MH S67M_012MH	0.0248 0.0013 0.0001	S69M_006MH S69O_006MH S71O_012MH S67M_012MH	0.0299 0.0021 0.0048 0.0030
Totals		0.000		0.000		0.0022		0.1252		0.3165		0.4434		0.5746

Table 5
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis – Wet Weather Results
Future Conditions Overflows – All Pumps Online

Basin	3-month Storm		1-year Storm		2-year Storm		5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)
DU01									S61W_007MH	0.0008	S61W_007MH S61W_006MH	0.0121 0.0058	S61W_007MH S61W_006MH	0.0233 0.0218
DU02														
DU03							S63I_017MH	0.0011	S63I_017MH S65I_001MH S65G_011MH	0.0071 0.0032 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0101 0.0058 0.0002 0.0005 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0127 0.0079 0.0006 0.0011 0.0005
DU04														
DU05													S69A1_017MH	0.0010
DU06					S69W_008MH S69W_004MH	0.0011 0.0001	S71S_005MH S71S_004MH S69W_008MH S69W_004MH S69W_009MH S69U_004MH S71S_014MH	0.0702 0.0330 0.0118 0.0050 0.0018 0.0007 0.0023	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1143 0.1136 0.0268 0.0205 0.0043 0.0072 0.0052 0.0037 0.0020 0.0010	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1594 0.1331 0.0458 0.0255 0.0104 0.0081 0.0063 0.0056 0.0046 0.0024	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_011MH S69W_009MH S69U_004MH S69S_012MH	0.1970 0.1491 0.0666 0.0300 0.0164 0.0088 0.0074 0.0074 0.0075 0.0039
DU07					S69M_006MH	0.0013	S69M_006MH	0.0090	S69M_006MH	0.0192	S69M_006MH S71O_012MH S67M_012MH	0.0252 0.0018 0.0002	S69M_006MH S69O_006MH S71O_012MH S71O_002MH S67M_012MH	0.0303 0.0024 0.0053 0.0001 0.0035
Totals		0.000		0.0000		0.0025		0.1349		0.3290		0.4630		0.6046

Table 6
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis – Wet Weather Results
Future Conditions Overflows – Backup Pump Offline

Basin	3-month Storm		1-year Storm		2-year Storm		5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)	Node	Volume (MG)
DU01									S61W_007MH	0.0008	S61W_007MH S61W_006MH	0.0121 0.0058	S61W_007MH S61W_006MH	0.0233 0.0218
DU02														
DU03							S63I_017MH	0.0011	S63I_017MH S65I_001MH S65G_011MH	0.0071 0.0032 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0101 0.0058 0.0002 0.0005 0.0001	S63I_017MH S65I_001MH S65I_008MH S65G_011MH S63I_002MH	0.0127 0.0079 0.0006 0.0011 0.0005
DU04														
DU05													S69A1_017MH	0.0013
DU06					S69W_008MH S69W_004MH	0.0011 0.0001	S71S_005MH S71S_004MH S69W_008MH S69W_004MH S69W_009MH S69U_004MH S71S_014MH	0.0707 0.0332 0.0118 0.0050 0.0018 0.0007 0.0023	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1168 0.1152 0.0268 0.0205 0.0043 0.0072 0.0053 0.0037 0.0020 0.0010	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_009MH S69U_004MH S69W_011MH S69S_012MH	0.1633 0.1345 0.0459 0.0255 0.0104 0.0081 0.0066 0.0056 0.0046 0.0024	S71S_004MH S71S_005MH S71S_014MH S69W_008MH S69Q_001MH S69W_004MH S69W_011MH S69W_009MH S69U_004MH S69S_012MH	0.2022 0.1506 0.0666 0.0300 0.0164 0.0088 0.0074 0.0077 0.0075 0.0039
DU07					S69M_006MH	0.0013	S69M_006MH	0.0090	S69M_006MH	0.0192	S69M_006MH S71O_012MH S67M_012MH	0.0252 0.0018 0.0002	S69M_006MH S69O_006MH S71O_012MH S71O_002MH S67M_012MH	0.0303 0.0024 0.0053 0.0001 0.0035
Totals		0.000		0.0000		0.0025		0.1356		0.3332		0.4687		0.6119

Table 7
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis – Wet Weather Results
Pump Station Summary

	Scenario	Peak Flow (MGD)	Peak Water Level in the Wet well (ft)	No. of Pumps Operated	Peak Velocity in 36" Force Main (fps)	Peak Pumping Rate (MGD)
3-month Storm	Baseline (All pumps online)	13.0	-19.95	2	3.22	14.7
	Baseline (Backup pump offline)	13.0	-19.95	2	3.22	14.7
	Future (All pumps online)	13.5	-19.97	2	3.30	15.1
	Future (Backup pump offline)	13.5	-19.97	2	3.30	15.1
1-year Storm	Baseline (All pumps online)	26.3	-18.43	3	6.31	28.8
	Baseline (Backup pump offline)	26.3	-18.43	3	6.31	28.8
	Future (All pumps online)	26.5	-18.49	3	6.35	29.0
	Future (Backup pump offline)	26.5	-18.49	3	6.35	29.0
2-year Storm	Baseline (All pumps online)	29.9	-17.78	3	7.29	33.3
	Baseline (Backup pump offline)	29.9	-17.78	3	7.29	33.3
	Future (All pumps online)	30.2	-17.84	3	7.36	33.6
	Future (Backup pump offline)	30.2	-17.84	3	7.36	33.6
5-year Storm	Baseline (All pumps online)	34.6	-17.48	4	8.16	37.3
	Baseline (Backup pump offline)	34.8	-16.90	3	8.49	38.8
	Future (All pumps online)	34.8	-17.55	4	8.19	37.4
	Future (Backup pump offline)	35.0	-17.04	3	8.51	38.9
10-year Storm	Baseline (All pumps online)	38.9	-16.81	4	9.29	42.4
	Baseline (Backup pump offline)	39.1	-15.87	3	9.62	44.0
	Future (All pumps online)	39.1	-16.79	4	9.34	42.6
	Future (Backup pump offline)	39.3	-15.84	3	9.67	44.2
15-year Storm	Baseline (All pumps online)	40.8	-16.23	4	9.88	45.1
	Baseline (Backup pump offline)	41.1	-15.13	3	10.03	45.8
	Future (All pumps online)	40.7	-16.85	4	9.68	44.2
	Future (Backup pump offline)	40.9	-15.77	3	9.99	45.7
20-year Storm	Baseline (All pumps online)	42.2	-16.32	4	10.18	46.5
	Baseline (Backup pump offline)	42.2	-15.16	3	10.07	46.0
	Future (All pumps online)	42.1	-16.51	4	10.14	46.3
	Future (Backup pump offline)	42.3	-15.37	3	10.06	46.0

5.1 Baseline Conditions

5.1.1 3-month, 1.5-hour Storm

The wet weather simulation first modeled a 3-month storm under scenario 1 (all 4 pumps are online) and no sewer overflows occurred. In general, sewers in basins DU03, DU06 and DU07 were found to have more significant capacity issues than sewers in other basins as determined through the inflow/infiltration evaluation. Specifically, water levels in five pipes in basins DU03, DU06 and DU07 rise above 75% of their pipe heights (i.e., a surcharge state greater than 0.75) under the 3-month storm.

Figure 5-1 is the hydraulic profile for a section of sewer in basin DU07 where a reach of 8-inch pipe along Dundalk Avenue connects to a downstream 12-inch pipe on Boston Avenue. The first pipe from the left has a surcharge state of 0.58 and experiences overflows under larger design storms (see below). A subsequent simulation was performed while three pumps are online (scenario 2) and again no overflows were observed. In either case, two pumps operate to handle the peak flows from the predicted 3-month, 1.5-hour storm and the peak velocity in the force main is below 7 feet per second.

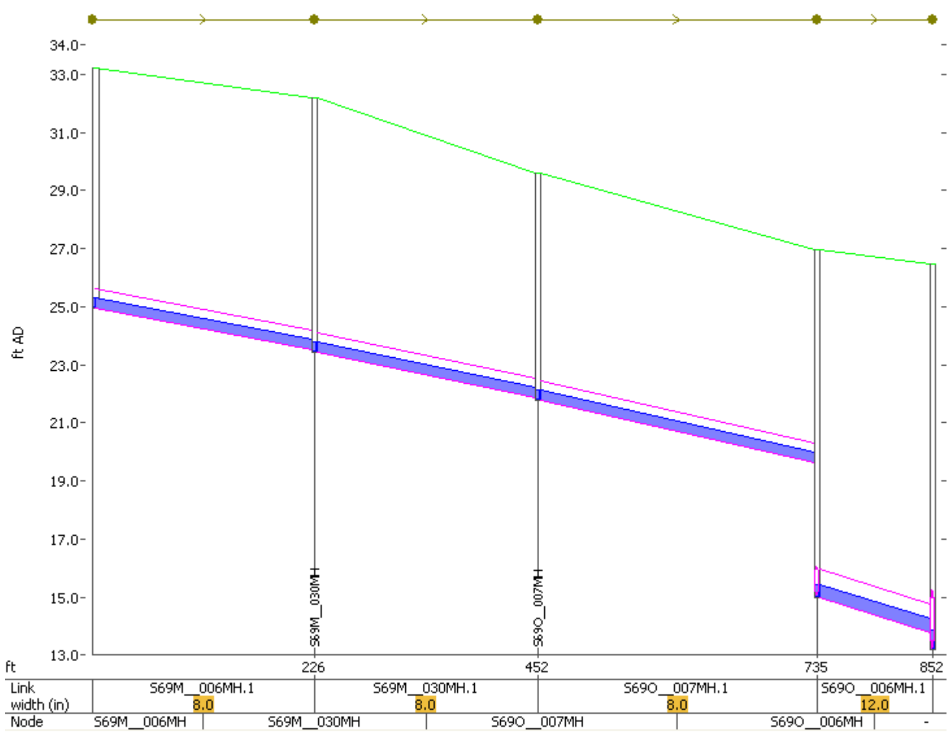


Figure 5-1: Hydraulic Profile for Sections from S69M__006MH to S69O__011MH under the 3-month Storm

5.1.2 1-year, 24-hour Storm

The results of this storm create additional surcharge conditions as compared to the 3-month, 1.5 hour storm under baseline conditions. For example, the water level in three manholes on the 8-inch line shown above in **Figure 5-1** rises to varying degrees and one manhole (S69M__006MH) surcharges to 2.44 feet below the rim elevation. Despite the observed surcharges, no overflows occurred under either pump station scenario for the 1-year, 24-hour storm.

Pumping the estimated peak inflow of 26.3 MGD, predicted by the model for the 1-year, 24-hour storm, triggers the operation of three pumps. During each pump station scenario analyzed for this storm, the wet well has additional remaining capacity (see **Table 7**) and the peak velocity within the force main is below 7 feet per second.

5.1.3 2-year, 24-hour Storm

For baseline conditions, the simulation for the 2-year, 24-hour storm resulted in three overflows with a total flood volume of 2,200 gallons. As expected, manhole S69M__006MH in the area depicted previously in **Figure 5-1** begins to overflow under this scenario. In addition, a pipe restriction is created on a section of 8-inch pipe along Portal Street in basin DU06; the hydraulic profile for this section is shown in **Figure 5-2**. Two manholes, S69W__008MH and S69W__004MH, overflow with a total volume of 1,000 gallons during the 2-year, 24-hour storm event.

The resulted peak flow of 29.9 MGD from this storm triggers operation of three pumps. During each pump station scenario analyzed for this storm, the wet well has additional remaining capacity (see **Table 7**). The 36-inch force main exceeds the 7 fps velocity threshold with a peak velocity of 7.3 fps. Therefore, an upgrade of the force main or frequent force main inspection is required to ensure the proper operation of the force main.

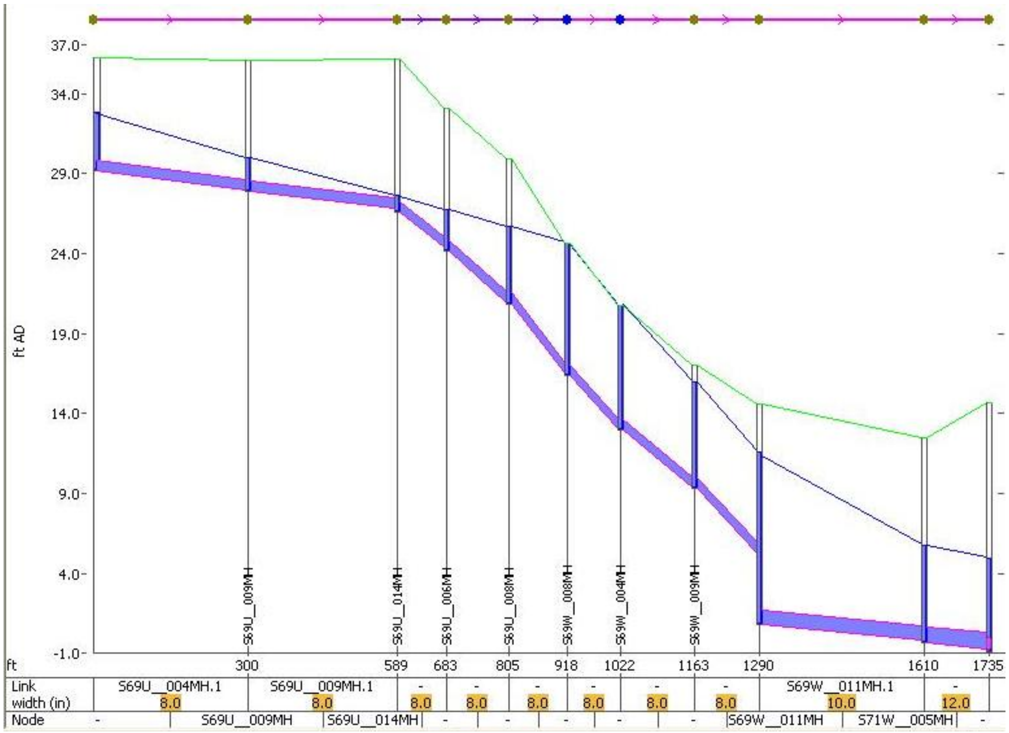


Figure 5-2: Hydraulic Profile for Sections from S69U__004MH to S71W__001MH under the 2-year Storm

5.1.4 5-year, 24-hour Storm

Under the 5-year, 24-hour storm, the total flood volume increases to 124,500 gallons while all pumps are online. The same overflows found in the 2-year simulation occurred at higher volumes while six (6) new manholes overflow. Two of these manholes are along the same sewer segment on Portal Street presented previously in **Figure 5-2**; the flood volume from the two manholes is 2,200 gallons. In addition to these, a new section of pipe in basin DU06 exhibits overflow; the profile is illustrated in **Figure 5-3**. The last manhole on the reach (S71S__014MH) receives flow from County basin BDU01 and has a small overflow of 1,100 gallons. Manhole S71S__004MH has a large overflow of 28,100 gallons and the greatest overflow at this site occurs at manhole S71S__005MH where meter BDU01 was placed. The outgoing 12-inch pipe connects two upstream 8-inch pipes (not modeled) and one upstream 15-inch pipe which may be a major cause of the surcharging and overflow. Lastly, a small overflow of 600 gallons occurs at manhole S63I__017MH in basin DU03 and the profile for this is presented in **Figure 5-4**. Manhole S63I__017MH lies at the downstream end of a pipe with steep slope and is susceptible to flooding under heavy flow.

The resulted peak flow of 34.6 MGD from this storm triggers operation of all four (4) pumps at the Dundalk Pump Station. It is noted that the pump operating guide for the Dundalk Pump Station provides on and off levels for three main pumps only. The on and off levels for the 4th pump are not available and the 4th pump will be turned on whenever required, depending on the magnitude of a storm event. For the purpose of this study, the on and off levels for the 4th pumps are set to the "high level alarm" level and the switch-on level of the 3rd pump, respectively. An additional 600 and 100 gallons of overflow were observed at manholes S71S__005MH and S71S__004MH respectively while only three pumps are online. During each pump station scenario, the wet well has additional remaining capacity. As with the 2-year, 24 hour storm, the predicted peak velocity is deemed excessive because it is greater than 7 fps.

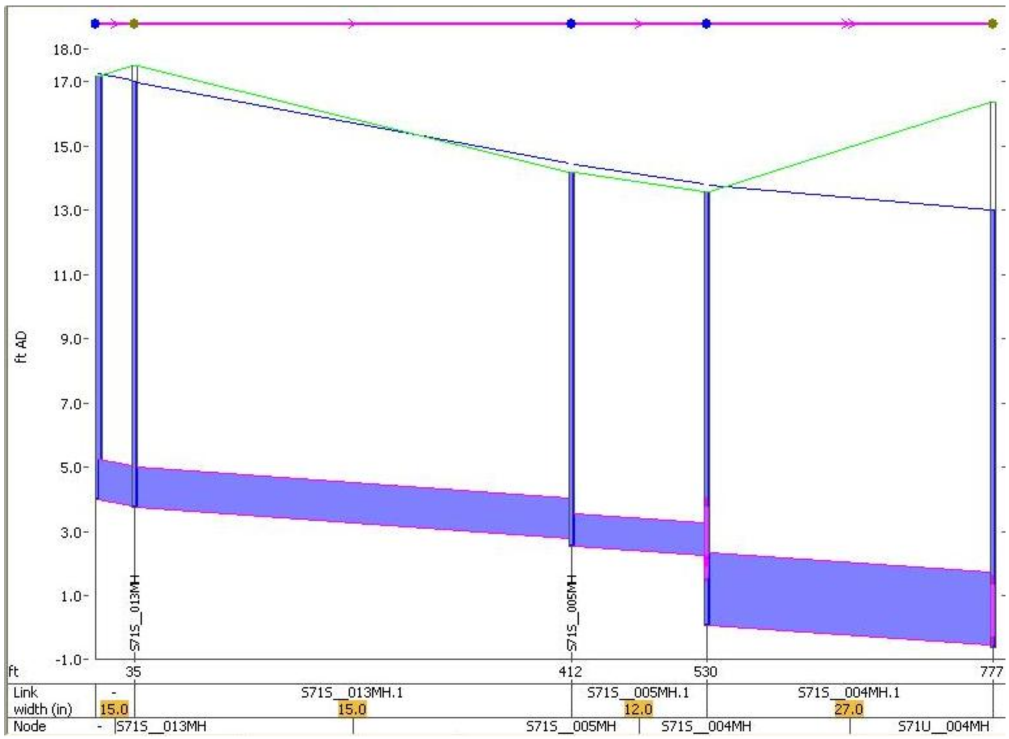


Figure 5-3: Hydraulic Profile for Sections from S71S__014MH to S71U__004MH under the 5-year Storm

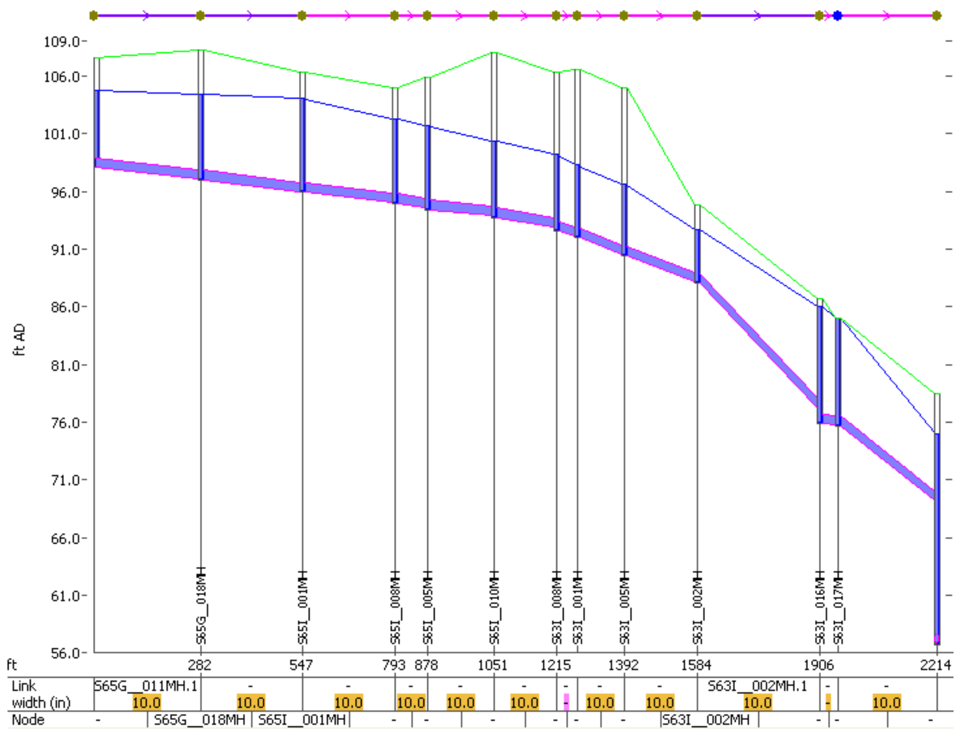


Figure 5-4: Hydraulic Profile for Sections from S65G__011MH to S63I__006MH under the 5-year Storm

5.1.5 10-year, 24-hour Storm

The simulation for the 10-year, 24-hour storm generated a flood volume of 312,500 gallons when all 4 pumps are online. In addition to overflows produced under the 5-year design storm, five (5) new manholes overflow. Of these, manhole S69W__011MH along the same sewer segment on Portal Street presented previously in **Figure 5-2** overflows with a flood volume of 1,700 gallons. Manholes S65G_011MH and S65I__001MH along the sewer segment presented in **Figure 5-4** overflow with a total flood volume of 2,900 gallons. In addition to the overflowing manholes described above, a pipe restriction is created in basin DU06 and this profile is depicted in **Figure 5-5**. Manhole S69Q__001MH overflows with a flood volume of 3,800 gallons. Lastly, a small overflow of 900 gallons occurs at manhole S69S__012MH on Manor Street in basin DU06 and the profile for this is presented in **Figure 5-6**.

This storm predicts a peak inflow of 38.9 MGD to the pump station and, as with 5-year, 24 hour storm, all 4 pumps operate with a peak pumping rate of 42.4 MGD. In the case when one pump is out of service, three overflows predicted under scenario 1 (all 4 pumps online) now occur at higher volumes and the total flood volume increases to 316,500 gallons. Under either pump station scenario, the wet well has additional remaining capacity and the peak velocity in the 36-inch force main exceeds the velocity threshold of 7 fps.

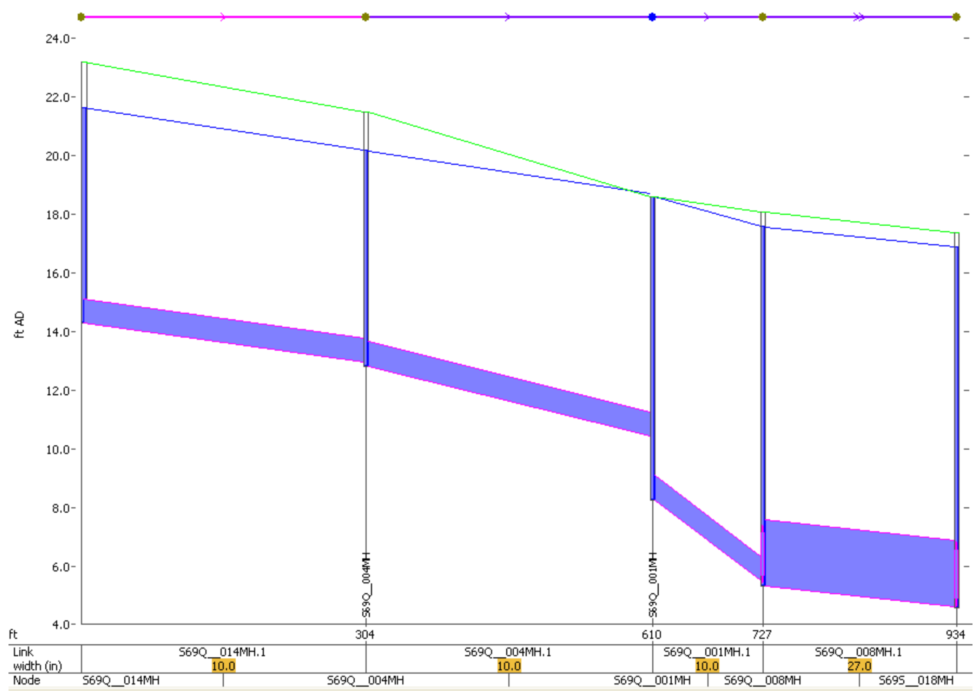


Figure 5-5: Hydraulic Profile for Sections from S69Q__014MH to S69S__018MH under the 10-year Storm

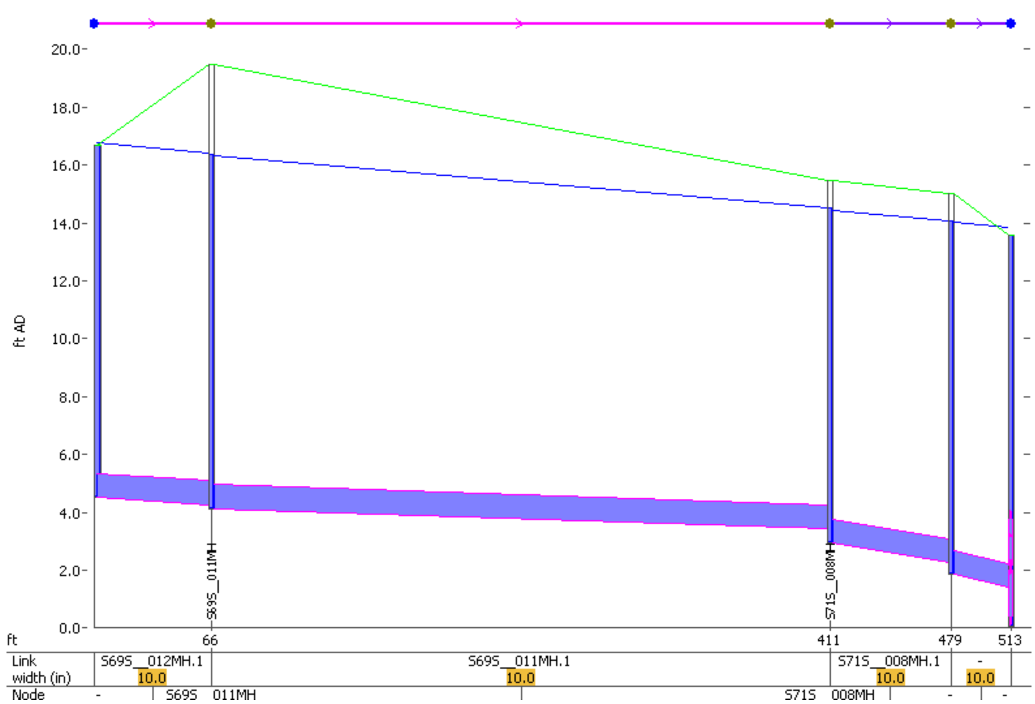


Figure 5-6: Hydraulic Profile for Sections from S69S__012MH to S71S__004MH under the 10-year Storm

5.1.6 15-year, 24-hour Storm

The total overflow volume increases to 436,600 gallons under the 15-year, 24-hour storm when all 4 pumps are online. In addition to overflows noted under the 10-year, 24-hour storm, five (5) new manholes overflow.

Of these, manholes S65I__008MH and S63I__002MH along the sewer segment presented previously in **Figure 5-4** overflow with a total flood volume of 300 gallons. A new section of sewer along Boston Avenue in basin DU07 exhibits overflow during the 15-year, 24-hour storm event (**Figure 5-7**). Manhole S71O__012MH overflows with flood volumes of 1,300 gallons. Other manholes along this segment are near flooding. The capacity issue at this site is partly due to the connection of 10-inch pipes to upstream 12-inch pipes as well as the existence of seven bends along the sewer line. In addition, manhole S61Y__003MH in basin DU01 overflows (**Figure 5-8**) with a flood volume of 7,400 gallons and field observations confirmed that this manhole is shallow, therefore susceptible to flooding during large storm events. Lastly, a pipe restriction is created on a section of pipe along O'Donnell Street in basin DU07 and the profile is illustrated in **Figure 5-9**. The last manhole on the reach (S67M__012MH) has a small overflow of 100 gallons during the 15-year storm event.

As with the 10-year, 24-hour storm, all four pumps operate to handle the predicted peak flow of 40.8 MGD for this storm. When only three pumps are online, the total flood volume increases to 443,400 gallons. Under either pump station scenario, the wet well has additional remaining capacity and the peak velocity in the 36-inch force main exceeds the velocity threshold of 7 fps.

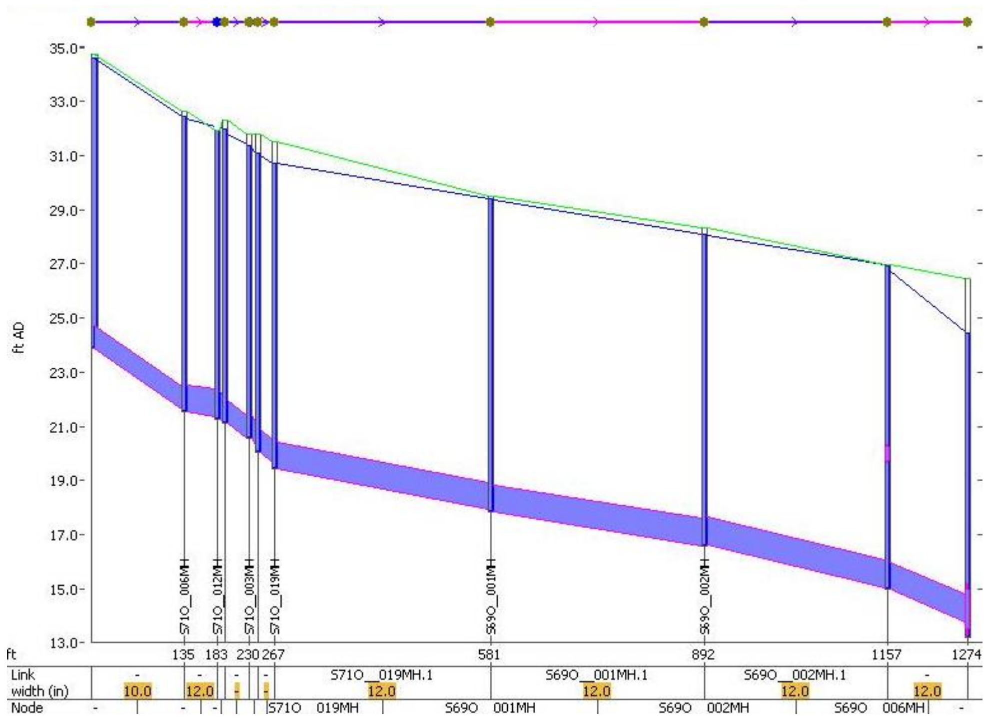


Figure 5-7: Hydraulic Profile for Sections from S71O__002MH to S69O__011MH under the 15-year Storm

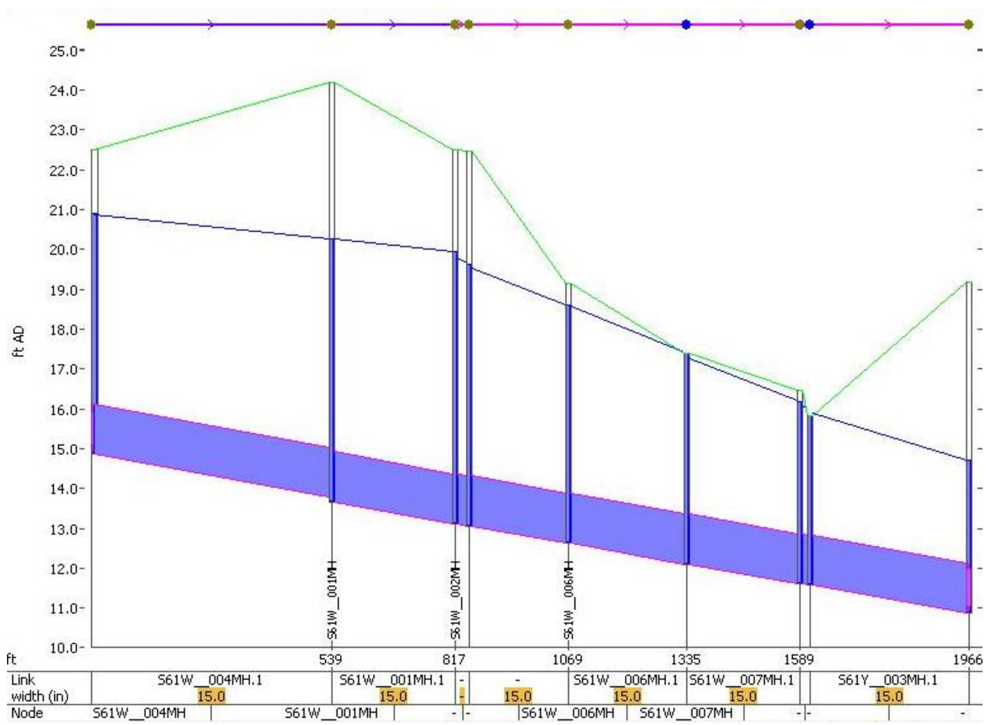


Figure 5-8: Hydraulic Profile for Sections from S61W__004MH to S61Y__005MH under the 15-year Storm

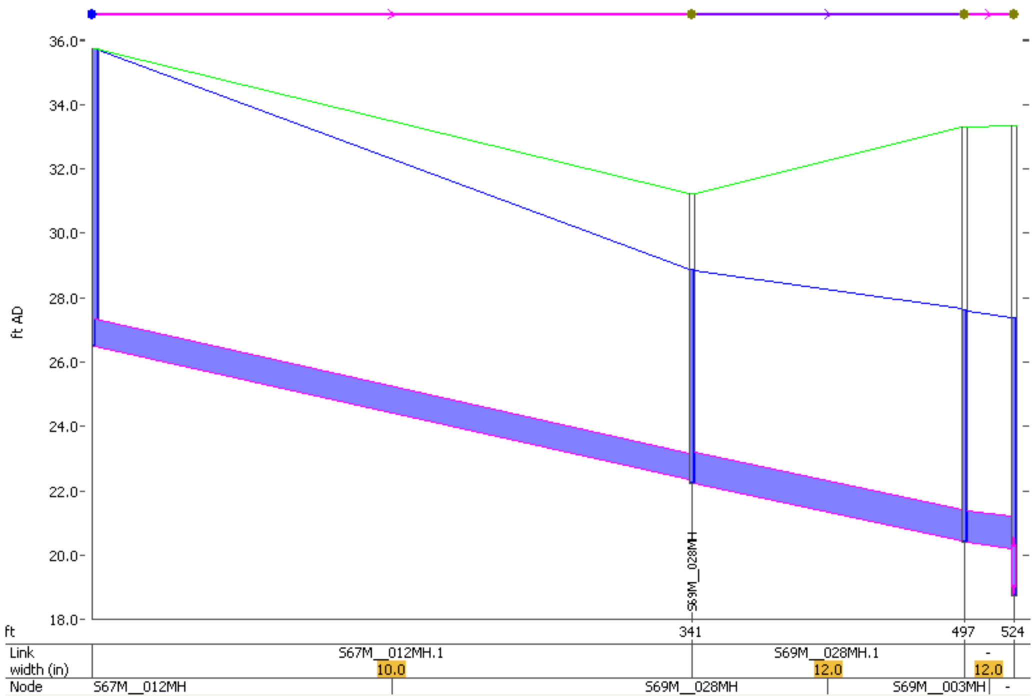


Figure 5-9: Hydraulic Profile for Sections from S67M__012MH to S69M__004MH under the 15-year Storm

5.1.7 20-year, 24-hour Storm

The overflow volume under baseline conditions increases to 566,800 gallons for the 20-year, 24-hour storm when all 4 pumps are online. In addition to overflows produced during the 15-year, 24-hour storm, thee (3) new manholes overflow. These include manhole S69O__006MH on the sewer segment presented previously in **Figure 5-7** and manhole S61W__007MH on the sewer segment presented previously in **Figure 5-8**. In addition to these, a new section of 8-inch pipe through Ft. Holabird Park in basin DU05 exhibits overflow; the profile is illustrated in **Figure 5-10**. Manhole S69A1_017MH has a small overflow of 800 gallons due to water backup from a 30-inch diameter interceptor to which the 8-inch line discharges. Constant surcharge at manhole S69A1_012MH was noted during manhole inspections along with surcharge evidence on the ground surface at manhole S69A1_007MH. RJN worked with the contractor to clean the pipe segment and discovered heavy sand accumulation in the approximately 1400 foot sewer line in the park between manholes S69A1_007MH and S71A1_015MH during the CCTV inspection. Hydraulic modeling confirmed that the observed surcharge was caused by sediments in the sewer line. A review of the hydraulic profile also revealed shallow manholes (e.g., manhole S69A1_017MH) and several flat and negative slope pipes (e.g., the pipe between manholes S67A1_012MH and S69A1_016MH). The latter could potential lead to accumulation of sediments and subsequent surcharge.

As with the 15-year, 24-hour storm, four pumps operate to accommodate the predicted peak flow of 42.2 MGD for the 20-year, 24-hour storm under scenario 1. Under scenario

2 (three pumps online), the overflow volume increase to 574,600 gallons. Under either pump station scenario, the wet well has additional remaining capacity and the peak velocity in the 36-inch force main exceeds the velocity threshold of 7 fps.

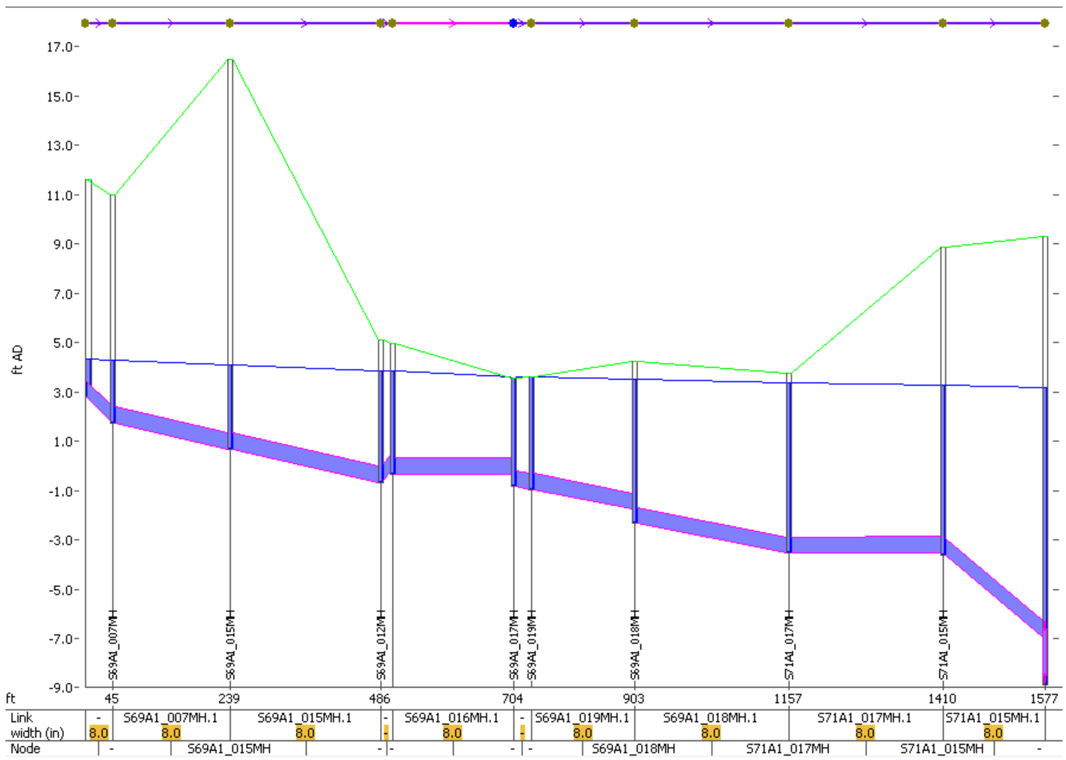


Figure 5-10: Hydraulic Profile for Sections from S69A1_006MH to S71A1_001MH under the 20-year Storm

5.2 Future Conditions

As with baseline conditions, all seven design storms were used for future conditions analysis with all pumps online and with backup pumps offline. Simulation results in tabular format are provided in **Tables 5 - 7**. The difference in flow between baseline and future conditions takes into account the contribution of population changes, industrial flow changes, and pipe deterioration. As expected, Year 2025 results are not dramatically different than Year 2007 results because base sanitary flows are small in relation to wet weather flows and the increase in base sanitary flows is not significant.

Specifically, there were no overflows under the 3-month storm and the 1-year, 24-hour storm events. Subsequent analyses on 2 to 20-year storms revealed various increases in flooded volume under future conditions and the percentage increase is generally in the range of 5% to 9%. The surcharge pattern and overflow locations remain the same under future conditions with only two (2) exceptions: (1) manhole S61Y__003MH was not flooded due to reconstruction of this manhole as a part of Chesapeake Commerce Center project, however this created a new overflowing manhole upstream: S61W__006MH; (2)

the last manhole (S71O__002MH) on the sewer line previously presented in **Figure 5-7** has a small overflow of 100 gallons during the 20-year storm under future conditions.

6.0 CAPACITY ANALYSIS SUMMARY

This report describes the capacity analysis performed for the Dundalk Sewershed under baseline and future conditions using the calibrated hydraulic model. With the model calibrated in previous efforts, base sanitary flow projections to Year 2025 were calculated based on expected population growth, infrastructure deterioration, and new developments. The Dundalk Sewershed was first analyzed to accommodate dry weather flows. System capacity was further evaluated for seven design storms including the 3-month, 1.5 hour storm, and the 1, 2, 5, 10, 15, and 20 year, 24 hour storms. **Table 8** provides a summary of number of overflows and flood volume predicted by the model for each of the design storms. The major conclusions for this study are summarized below.

(1) Base sanitary flow is small in comparison to rainfall dependent inflow and infiltration and the latter is the leading factor in causing sewer overflows. Simulation results under future conditions are similar to the results under baseline conditions due to the fact that a majority of the sewershed is well developed.

(2) There are no capacity issues under dry weather conditions. During wet weather conditions, the model indicates overflows in meter basins DU01, DU03, DU05, DU06, and DU07 with the majority being in basin DU06.

(3) Three main pumps and the wet well at the Dundalk Pump Station have sufficient capacity to handle peak dry weather flow. During wet weather storm events (a 5-year storm or above), simulations suggest operation of all 4 pumps at the pump station to handle peak wet weather flows. Nevertheless, the wet well has additional remaining capacity while one pump is offline for maintenance. No pump station upgrade is required. For a 2-year storm or above, the 36-inch force main is not in compliance with the velocity threshold of 7 feet per second; an upgrade of the force main or frequent force main inspection is required to ensure its proper operation.

(4) Under the baseline condition, the total flood volume increases from 2,200 gallons for the 2-year storm to 566,800 gallons (all 4 pumps online) and 574,600 gallons (three pumps online) for the 20-year storm. This represents a 257 times increase and a 260 times increase in flood volume when all 4 pumps and three pumps are online, respectively.

(5) Under the future conditions, the total flood volume increases from 2500 gallons for the 2-year storm to 604,600 gallons (all 4 pumps online) and 611,900 gallons (three pumps online) for the 20-year storm. This represents a 241 times increase and a 244 times increase in flood volume when all 4 pumps and three pumps are online, respectively.

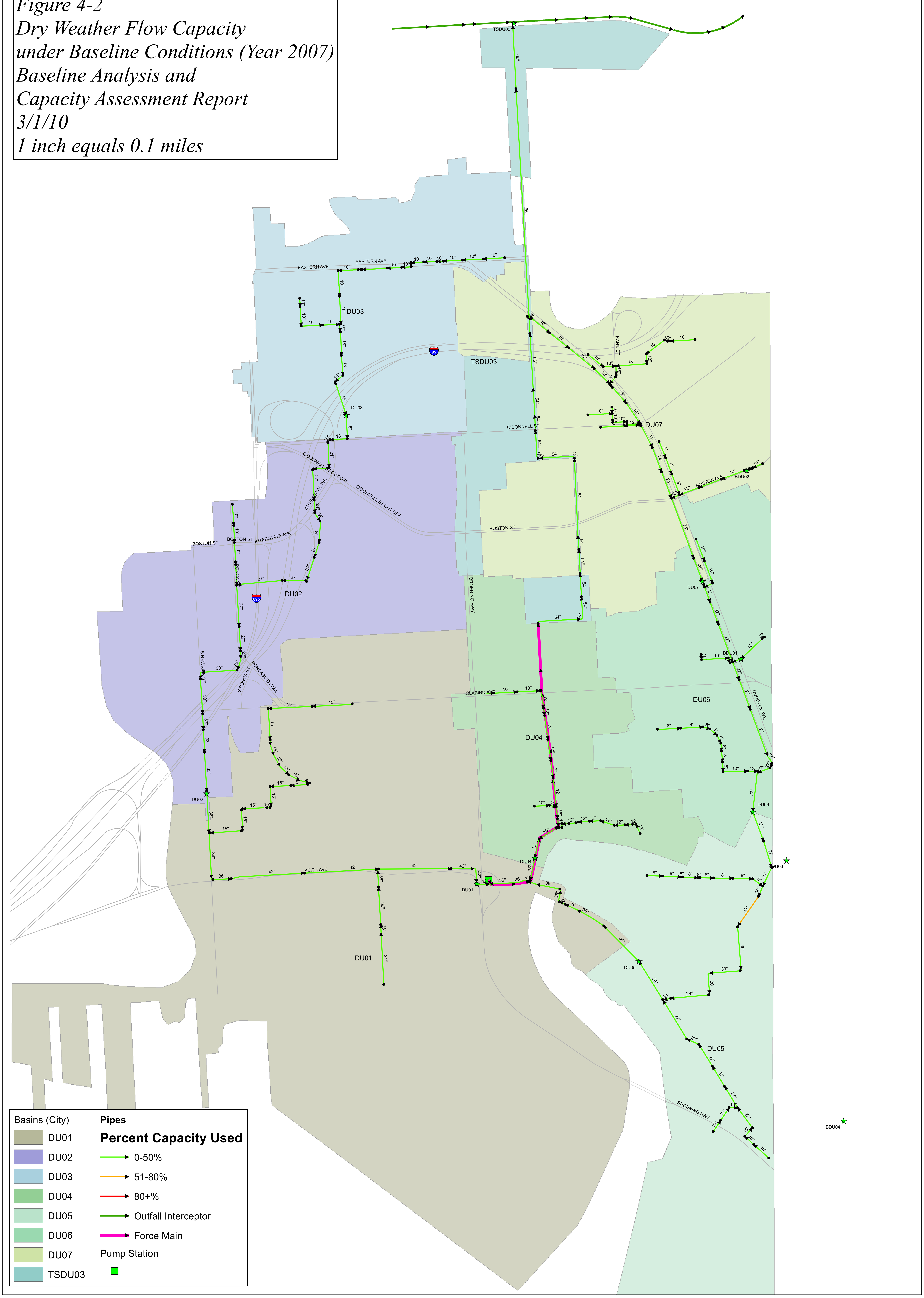
Table 8
Dundalk Baseline Analysis and Capacity Assessment Report: Capacity Analysis Summary
Dundalk Overflow Summary

Scenario	Design Storm	No. of Overflows	Flood Volume (Gallons)
Baseline Condition (All pumps online)	3-month	0	0
	1-year	0	0
	2-year	3	2,200
	5-year	9	124,500
	10-year	14	312,500
	15-year	19	436,600
	20-year	22	566,800
Baseline Condition (Backup pump offline)	3-month	0	0
	1-year	0	0
	2-year	3	2,200
	5-year	9	125,200
	10-year	14	316,500
	15-year	19	443,400
	20-year	22	574,600
Future Condition (All pumps online)	3-month	0	0
	1-year	0	0
	2-year	3	2,500
	5-year	9	134,900
	10-year	15	329,000
	15-year	20	463,000
	20-year	23	604,600
Future Condition (Backup pump offline)	3-month	0	0
	1-year	0	0
	2-year	3	2,500
	5-year	9	135,600
	10-year	15	333,200
	15-year	20	468,700
	20-year	23	611,900

City of Baltimore
Dundalk Collection System Evaluation and Sewershed Plan
Project No. 1047
Figure 1-1
Dundalk Sewershed Map
Baseline Analysis and Capacity Assessment Report
10/30/09
1 inch equals 0.25 miles
N
Location Map
Legend
Dundalk Sewershed
Sanitary Sewer Pipes

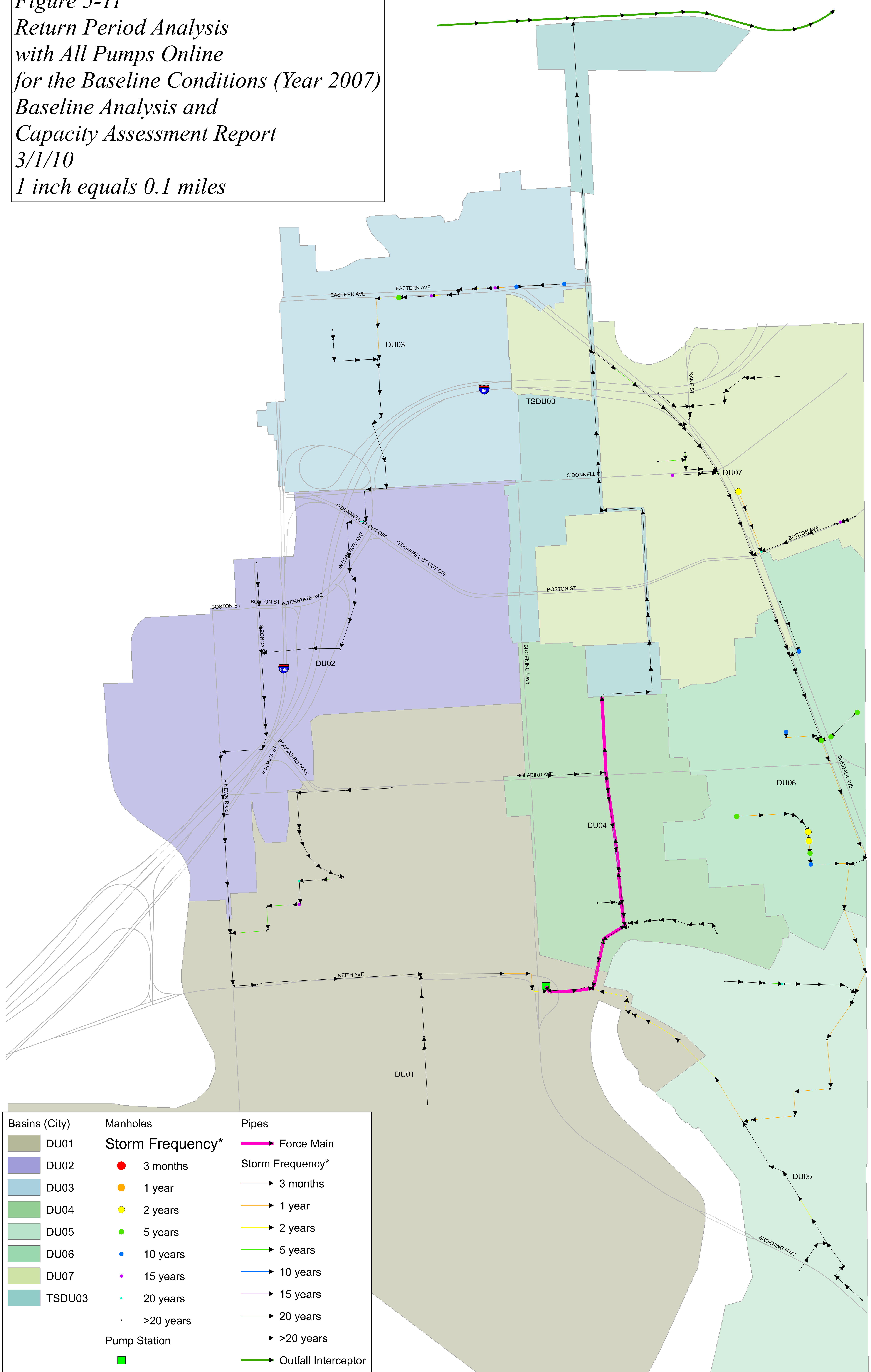
City of Baltimore
Dundalk Collection System
Evaluation and Sewershed Plan
Project No. 1047
Figure 3-1
Rain Dependent Inflow/
Infiltration Severity Map
Baseline Analysis and
Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles

City of Baltimore
Dundalk Collection System Evaluation and Sewershed Plan
Project No. 1047
Figure 4-2
Dry Weather Flow Capacity under Baseline Conditions (Year 2007)
Baseline Analysis and Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles



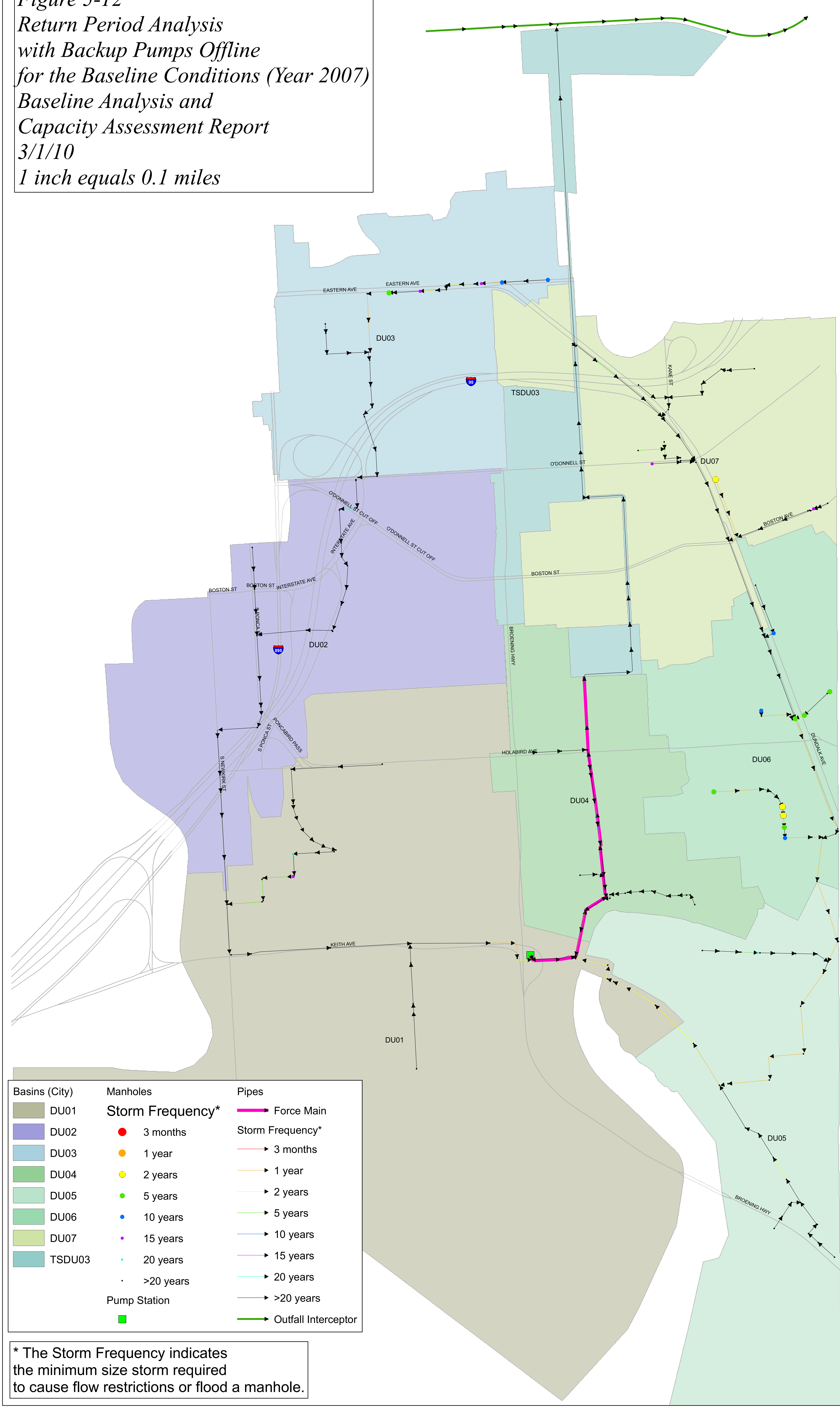
City of Baltimore
Dundalk Collection System Evaluation and Sewershed Plan
Project No. 1047
Figure 4-3
Dry Weather Flow Capacity under Future Conditions (Year 2025)
Baseline Analysis and Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles

City of Baltimore
Dundalk Collection System Evaluation and Sewershed Plan
Project No. 1047
Figure 5-11
Return Period Analysis with All Pumps Online for the Baseline Conditions (Year 2007)
Baseline Analysis and Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles



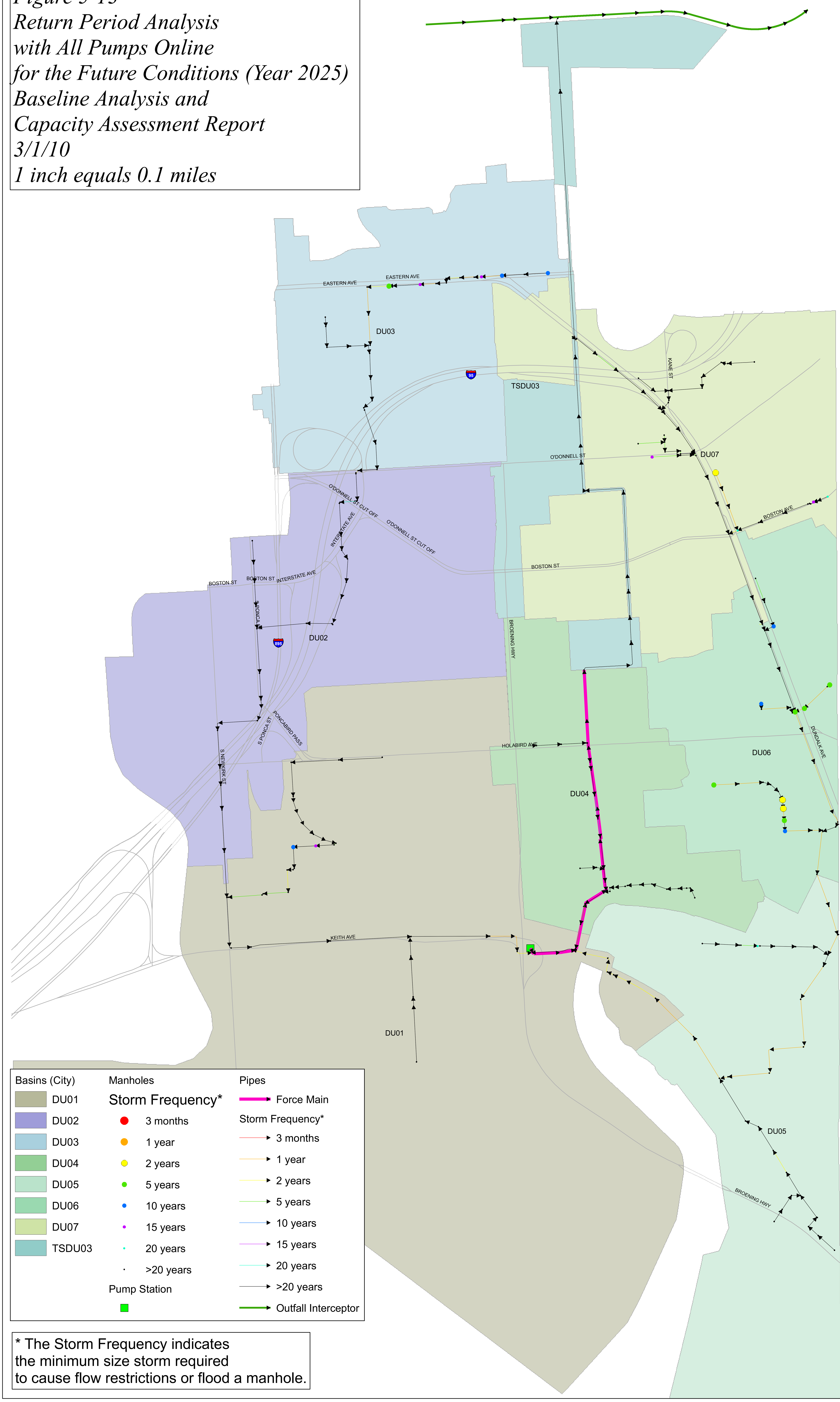
* The Storm Frequency indicates the minimum size storm required to cause flow restrictions or flood a manhole.

City of Baltimore
Dundalk Collection System Evaluation
and Sewershed Plan
Project No. 1047
Figure 5-12
Return Period Analysis
with Backup Pumps Offline
for the Baseline Conditions (Year 2007)
Baseline Analysis and
Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles



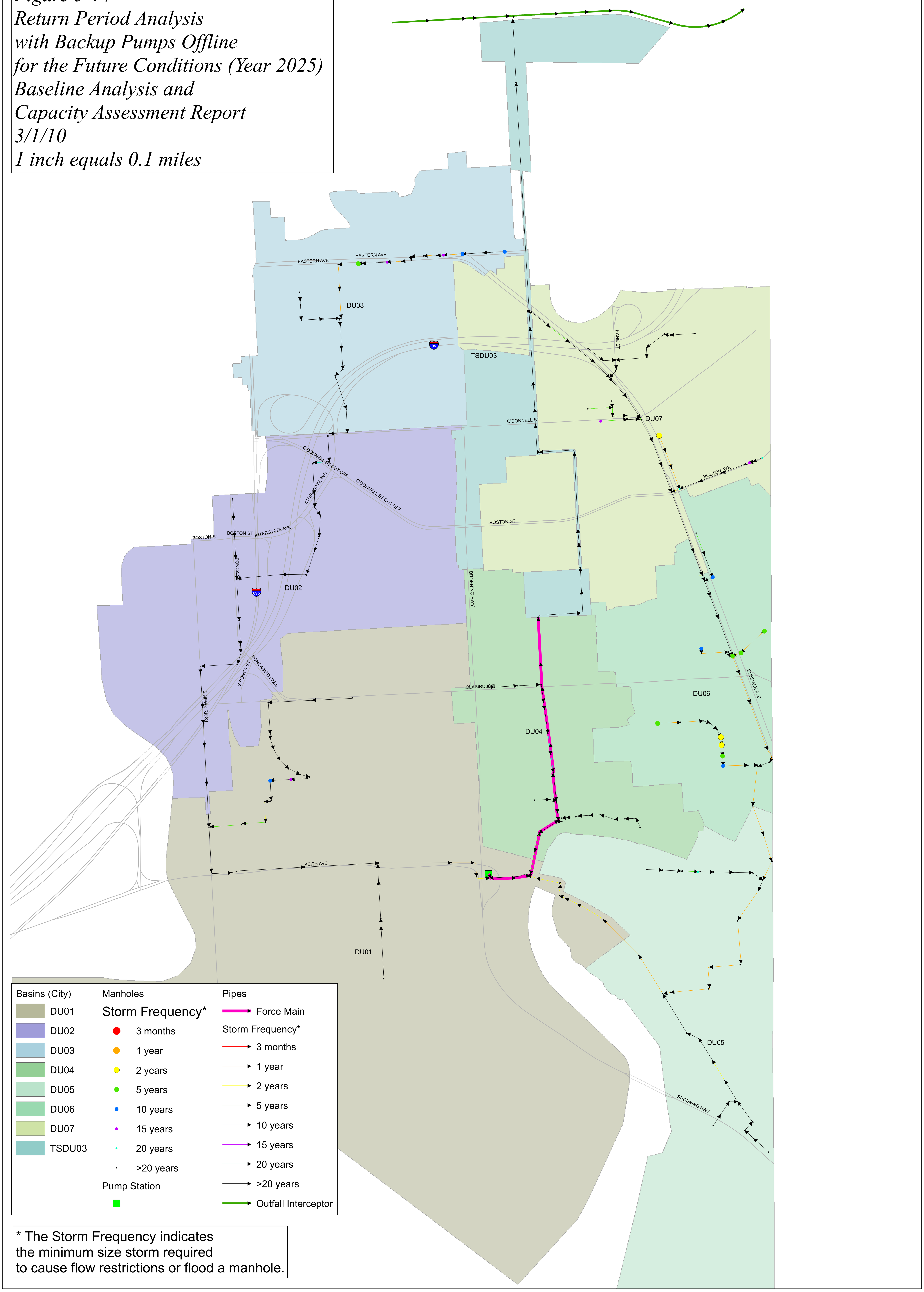
* The Storm Frequency indicates
the minimum size storm required
to cause flow restrictions or flood a manhole.

City of Baltimore
Dundalk Collection System Evaluation and Sewershed Plan
Project No. 1047
Figure 5-13
Return Period Analysis with All Pumps Online for the Future Conditions (Year 2025)
Baseline Analysis and Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles



* The Storm Frequency indicates the minimum size storm required to cause flow restrictions or flood a manhole.

City of Baltimore
Dundalk Collection System Evaluation
and Sewershed Plan
Project No. 1047
Figure 5-14
Return Period Analysis
with Backup Pumps Offline
for the Future Conditions (Year 2025)
Baseline Analysis and
Capacity Assessment Report
3/1/10
1 inch equals 0.1 miles



* The Storm Frequency indicates
the minimum size storm required
to cause flow restrictions or flood a manhole.